REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-01-

O 470

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REP(
	28 AUGUST 2001	FINAL 01 MAR 98 TO 28 AUG 01

4. TITLE AND SUBTITLE
Develop and Demonstrate Real-Time Wavelet Based Automatic Target Recognition Using Sonar and Synthetic Aperture Radar (SAR) Data

5. FUNDING NUMBERS
F49620-97-1-0465

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20011005 141

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NM
801 N. Randolph Street Room 732
Arlington, VA 22203-1977

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-98-C-0017

11. SUPPLEMENTARY NOTES

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13. ABSTRACT *(Maximum 200 words)*
The DARPA project, "Develop and Demonstrate Real-Time Wavelet Based Automatic Target Recognition Using Sonar and Synthetic Aperture Radar (SAR) Data" was initiated March 30, 1998 with a kick-off meeting attended by personnel from Rice University CML, Northrop Gramman ESSD and DARPA DSO. The overall goal is the transition of DARPA sponsored university research into a fielded systems demonstration using a liaison between a university and an industrial partner familiar with the specific defense application. In the first year of this contract Northrop Grumman obtained and applied Rice CML's wavelet-based compression/expansion algorithms to sonar and SAR data collected for automatic target recognition. Also Northrop Gramman sent Rice CML sonar data collected for automatic target recognition. Also Northrop Grumman sent Rice CML's sonar data sets and references to MSTAR data sets for use in the development of wavelet-based detection techniques. In the second year Northrup Grumman retained its ATR algorithms for use on compressed data and also evaluated denoising and segmentation algorithms based on Hidden Markov Trees (HMT) defined on wavelet coefficients. These HMT technologies were developed by Rice CML during the first year of the contract. In the third year Northrup Grumman made ready a demonstration of wavelet based compression/expansion on Global Hawk SAR data running in real time using the Real Time ATR (RT-ATR) Lab at the DARPA Technology Integration Center (TIC) in Arlington, VA. Also available for demonstration is the wavelet-based Rice developed denoising algorithms.

14. SUBJECT TERMS

15. NUMBER OF PAGES
4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

Final Report Year 3

**Develop and Demonstrate Real-Time Wavelet Based
Automatic Target Recognition Using Sonar and
Synthetic Aperture Radar (SAR) Data
Contract No. F49620-98-C-0017**

**Prepared for DARPA/DSO
By
Northrop Grumman ES - STC
August 28, 2001**

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1. Introduction

The DARPA project, "Develop and Demonstrate Real-Time Wavelet Based Automatic Target Recognition Using Sonar and Synthetic Aperture Radar (SAR) Data" was initiated March 30, 1998 with a kick-off meeting attended by personnel from Rice University CML, Northrop Grumman ESSD and DARPA DSO. The overall goal is the transition of DARPA sponsored university research into a fielded systems demonstration using a liaison between a university and an industrial partner familiar with the specific defense application. In the first year of this contract Northrop Grumman obtained and applied Rice CML's wavelet-based compression/expansion algorithms to sonar and SAR data collected for automatic target recognition. Also Northrop Grumman sent Rice CML sonar data sets and references to MSTAR data sets for use in the development of wavelet-based detection techniques. In the second year Northrop Grumman retrained its ATR algorithms for use on compressed data and also evaluated denoising and segmentation algorithms based on Hidden Markov Trees (HMT) defined on wavelet coefficients. These HMT technologies were developed by Rice CML during the first year of the contract. In the third year Northrop Grumman made ready a demonstration of wavelet based compression/expansion on Global Hawk SAR data running in real time using the Real Time ATR (RT-ATR) Lab at the DARPA Technology Integration Center (TIC) in Arlington, VA. Also available for demonstration is the wavelet-based Rice developed denoising algorithms.

2. Milestones

The third year of the contract concentrated on the demonstration of wavelet based companding and wavelet based denoising on SAR imagery for use with AR algorithms. All milestones and tasks schedules for the third year were completed as shown in Table 1.

Milestones	Scheduled Completion	Completed
1. Optimized Companding, ATR effective and recommended	3-3-2000	9-1-2000
2. Progress Report No. 3 delivered	9-1-2000	9-1-2000
3. Algorithms/SW ready for DOD application/demonstration	9-1-2000	8-1-2001
4. Third Year Technical & Invention Report delivered (note: A six month no-cost extension was requested from and granted by sponsor 3-8-2001)	5-31-2001	8-28-2001

Table 1. Completed Milestones

When in the third year of the contract it was realized that due to a staffing shortage certain milestone dates would not be met a six month no-cost extension was requested from the sponsor and was granted by the sponsor in the early part of March, 2001.

3. Description of Work Completed over Third Year

Figure 1 diagrams the primary software modules prepared for the demonstration made ready at the RT-ATR Lab, Figure 2, where Global Hawk data is used to demonstrate the effects of compression/expansion and denoising on SAR ATR performance. Although initial work on compression/expansion studies on ATR performance used Rice's wavelet-based compander, a JPEG-2000 wavelet-based compression/expansion algorithm was chosen for the real time demonstration since the C compiled code runs much faster than the MATLAB based Rice code. Two UNIX shell scripts were written; the first to strip the header from a reference file and format the data for the JPEG-2000 code and the second to re-attach the header and re-format the reconstructed image data as NTIF. Operating on a 40 megabyte image, the total process runs in about 2 minutes on a single SGI machine at the RT-ATR Lab.
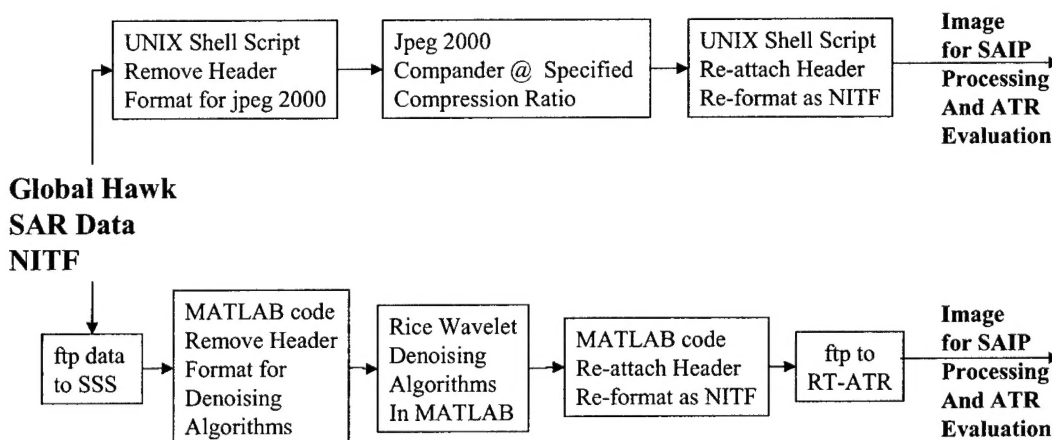

Figure 1; Processing Stream for Demonstration of Wavelet Based Compression / Expansion and Denoising

The second available demonstration uses wavelet-based denoising algorithms coded in MATLAB. Similar modules were written to format the data for the MATLAB code and then reformat it as NTIF data. Data was ftp'd to the SAIP Surrogate System (SSS) facility (in Baltimore) to an SGI machine having MATLAB, where 40 megabyte images could be processed in about 30 minutes. The denoised images were then sent back to the RT-ATR Lab for ATR performance evaluation. A classified report, reference 5.1, is available on the results of these studies. An unclassified example of the denoising algorithms run on sonar data is shown in Figure 3. Also, examples of unclassified targets and Global Hawk SAR imagery, on which compression/expansion was run, are shown in Figures 4, 5 and 6.
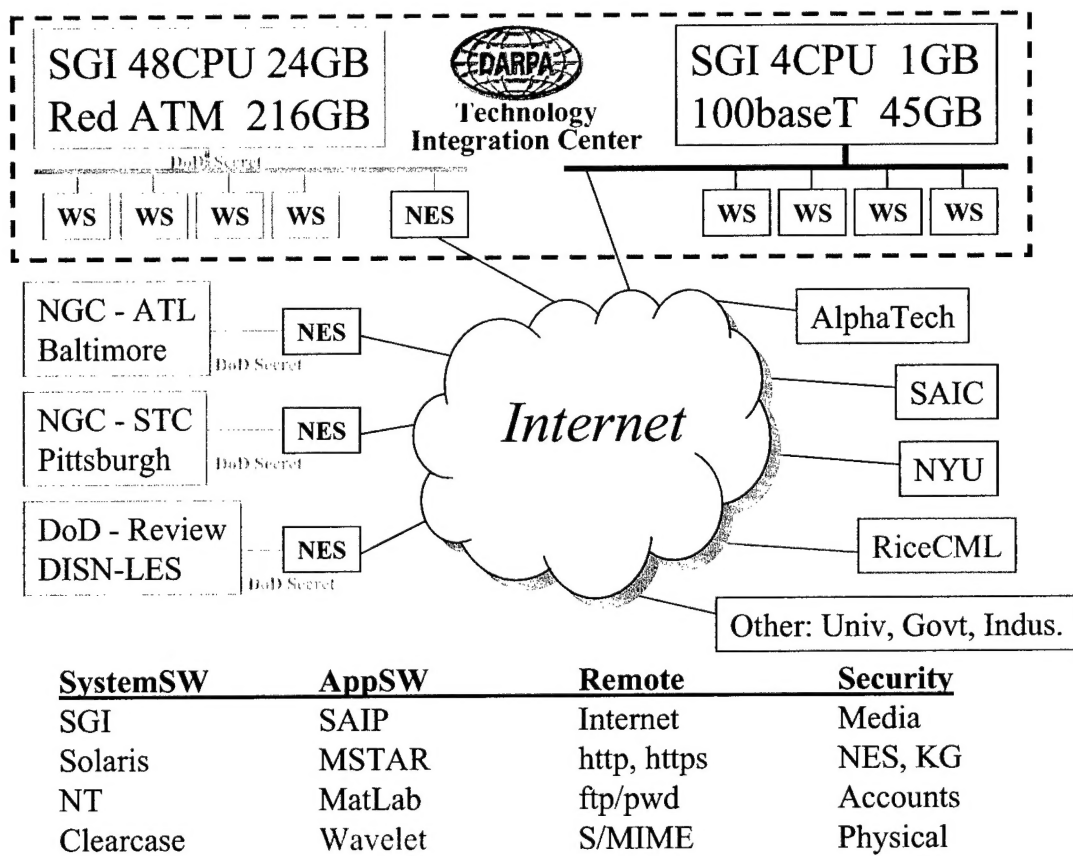
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| Red ATM 216GB | | Technology Integration Center | | 100baseT 45GB | |

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Other: Univ, Govt, Indus.

SystemSW	AppSW	Remote	Security
SGI	SAIP	Internet	Media
Solaris	MSTAR	http, https	NES, KG
NT	MatLab	ftp/pwd	Accounts
Clearcase	Wavelet	S/MIME	Physical

Figure 2. Computer Communication Architecture at the RT_ATR Lab
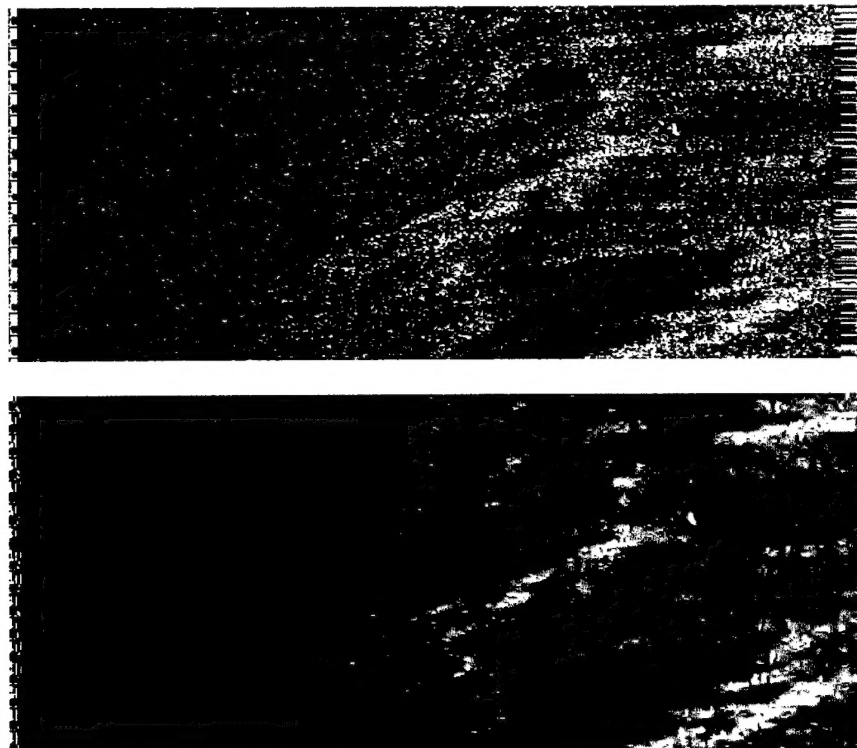

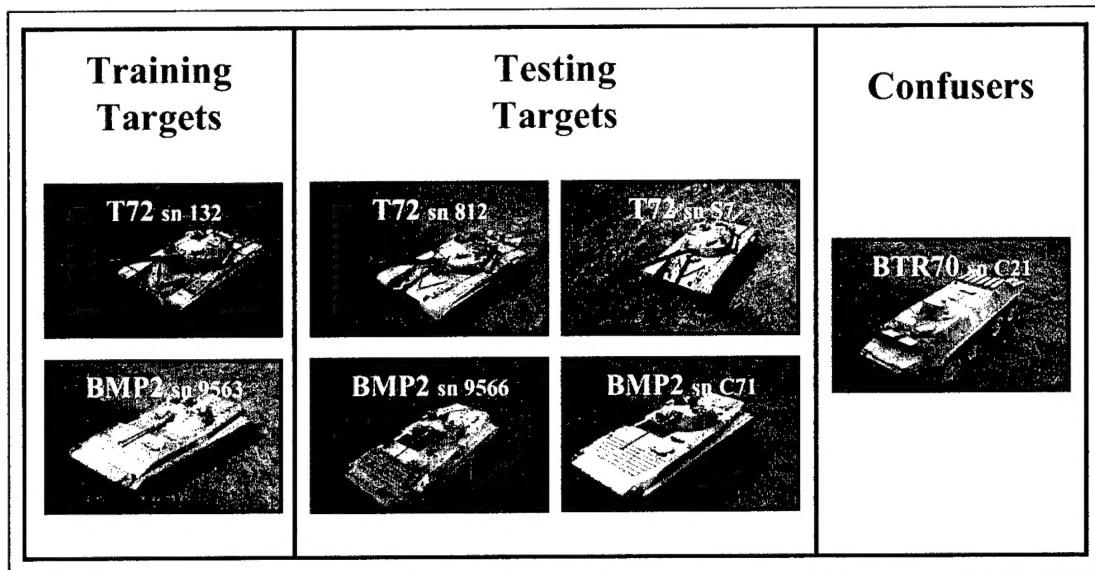**Figure 3. Wavelet-based denoising of sidescan sonar image**

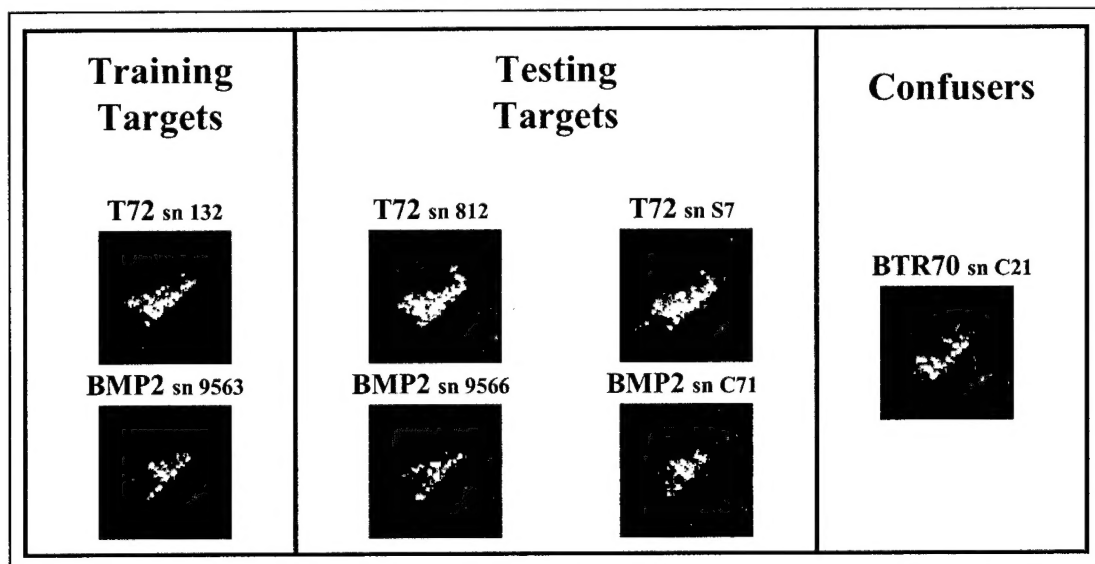Figure 4. Vehicles Used for Wavelet SAR Image Compression ATR Study

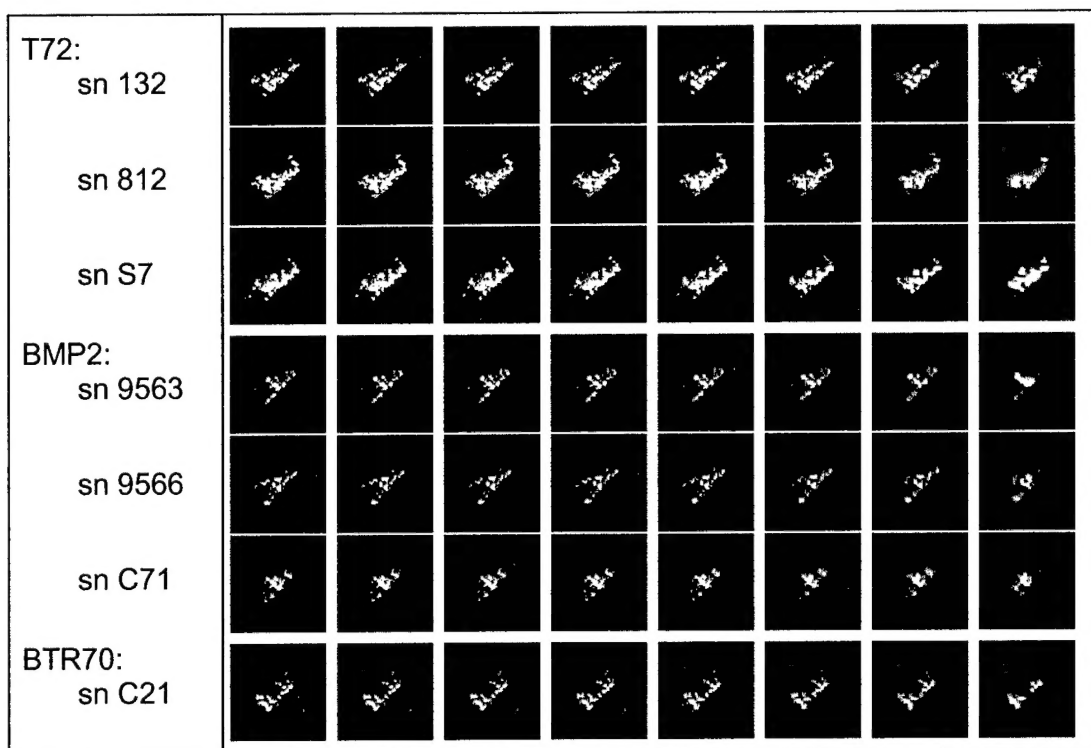Figure 5. Representative SAR Images of Vehicles Used

Figure 6. Matrix of CODEC SAR Target Imagery

4. Summary and Conclusions

The current year's effort demonstrated real time compression/expansion of SAR data. Although the SAIP processed ATR results are classified, earlier work on this contract in previous years using unclassified data showed that both SAR ATR for military vehicles and sonar ATR for mine-hunting could tolerate compression ratios up to 64:1.

Although funding only permitted the compander to be implemented as a real time demonstration, denoising which shares much of the same algorithms complexity could easily be implemented in compiled code to run in real time.

As a result of knowledge and expertise gained on this contract in liaison with Rice University, Northrop Grumman has:

1. Upgraded the US Navy's AN/AQS-14A Search Sonar System using real time compression of 16:1 for transmission of sonar data over an HF radio link.
2. Proved the feasibility of wavelet-based compression and expansion of 2D image data for use in ATR systems.
3. Gained knowledge in the use of Hidden Markov Models employing Hidden Markov Trees for 2D image segmentation.
4. Started development of wavelet-based structured de-cluttering of sonar images.
5. Started development of wavelet-based blind segmentation of 2D images without using tesselations.
6. Developed working relation with Computational Mathematics Laboratory (CML) personnel of Rice University

5. Reference

1. Dr. Andrew Miklich, "Final DARPA Wavelet Report Year 3 – Addendum" 2001, Contract No. F49620-98-C-0017, Northrop Grumman internal report.